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RECOMMENDATIONS for DRYING CALIFORNIA BLACK OAK

Harvey H. Smith

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FOREWORD

California black oak, a hardwood, does not dry nearly so easily as the softwood species such as ponderosa pine, sugar pine, and Douglas-fir with which it grows. Lack of information on the drying of black oak has been a limiting factor in its utilization. In any study of the utilization of California black oak the drying, therefore, becomes an important consideration.

This paper reports the results of a drying study made as part of a cooperative study of the utilization of California black oak. The co-operators were the Diamond Match Company, (now Diamond National Corp.) Chico, California, the University of California Forest Products Laboratory, the Pacific Southwest Forest and Range Experiment Station of the U.S. Forest Service, and the U.S. Forest Products Laboratory at Madison, Wisconsin.

The U.S. Forest Products Laboratory made log-grade and yield studies to determine the quality of oak timber harvested on the company's timberlands. Sixty-two thousand board feet of lumber from these studies was used to determine the best procedure for drying black oak to a final moisture content of 6 to 8 percent; the California Forest Products Laboratory used 7,200 board feet of green lumber and 2,000 board feet of pre-dried lumber for drying studies in an experimental kiln; and the Pacific Southwest Forest and Range Experiment Station dried 52,800 board feet experimentally at the company plant in Chico. The Chico experiments are reported here.

Much of the credit for the success of these drying studies goes to the operating personnel of the Diamond National Corporation who carried out the extra work along with their regular duties.

RECOMMENDATIONS FOR DRYING CALIFORNIA BLACK OAK

By

Harvey H. Smith, Forest Products Technologist

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PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
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RECOMMENDATIONS FOR DRYING CALIFORNIA BLACK OAK

By

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Previous studies of the drying of California black oak[1/] showed that 4/4 lumber could be successfully dried by first air-drying it to a moisture content of 20 percent and then kiln drying to the desired low final moisture content. This is the procedure used extensively in the commercial drying of eastern and southern oak. These studies also showed that the local black oak is subject to serious drying degrade (checking, collapse and honeycomb) if kiln dried green-from-the-saw by anything but a very mild, slow-drying schedule.

With these earlier studies and accepted commercial practice for oak in other parts of the country as guides, three drying methods were studied in relatively large-scale experiments at the Diamond National plant in Chico:

1. Air-drying or yard drying followed by kiln drying
2. Shed drying followed by kiln drying
3. Low-temperature drying followed by kiln drying.

EXPERIMENTAL PROCEDURE

All study lumber was box piled by hand into unit packages of 4 x 4 x 16 feet, using a sticker guide (fig. 1). Standard stickers, 1 x 2 x 48 inches in size, were placed 12 per course, or slightly less than 18 inches apart.

AIR DRYING

Eighteen units of oak lumber were piled for yard drying with two pile spacings. Three piles of 3 units high were spaced 15 inches apart to form 1 block of 9 units. Three piles of 3 units high were spaced 30 inches apart to form a second block of 9 units. Units of nonstudy lumber were piled adjacent to the study lumber, using the same spacing, to isolate the study lumber (figs. 2 and 3). Twenty-four samples were used to determine the progress of drying on the yard. These samples were again used in the final kiln drying.

1/ Reported in Forest Research Note 62, Seasoning California Black Oak, California Forest and Range Experiment Station, 8 pp., July 1949; and Forest Research Note 75, Further experiments in seasoning California black oak, Pacific Southwest Forest and Range Experiment Station, 11 pp., September 1950.

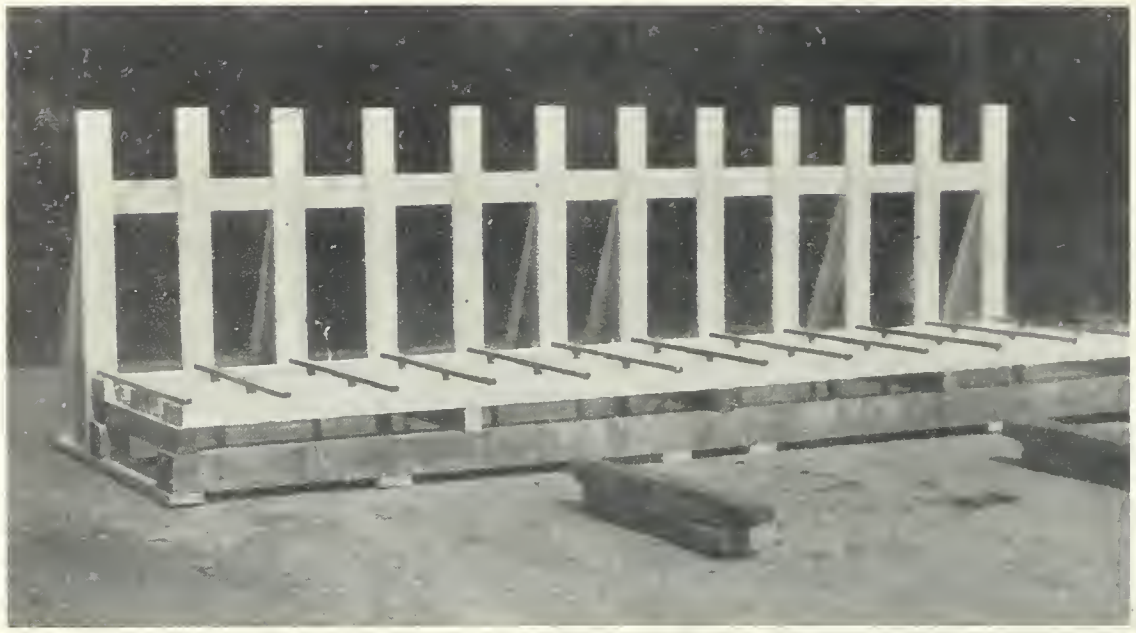

Figure 1.--Sticker guide used in piling all lumber at Chico.

SHED DRYING

Lumber that was graded 3B and lower on the green chain was placed in 12 unit packages, and these were stacked 3 high making 4 piles in a closed storage shed for drying. Piles 1 and 2 were placed edge to edge. The space between piles 2 and 3 was only sufficient to allow removal of the samples (about 15 inches). Piles 3 and 4 were placed edge to edge.

Twelve samples were placed in piles 2, 3, and 4 to follow the progress of drying. These samples were also used in the final kiln drying.

LOW-TEMPERATURE DRYING

Forced air-drying, low-temperature drying, and accelerated air-drying are all terms that describe a method of predrying lumber used extensively in the South and the Southeast. This method is faster than conventional air-drying, and permits drying conditions to be controlled so that defects are held to a minimum. A wide variety of equipment is now available for this method. Lumber predried in this way is usually kiln dried to the desired low final moisture content.

This phase of the study was done in two kilns operated at conditions considered normal for this type of drying.

Eight units of green lumber were piled in each of the two "low-temperature driers" for study of mild and severe schedules. A dry bulb (D.B.) temperature of 100° F. with a 4° F. wet bulb (W.B.) depression was used in the mild schedule. The humidity was reduced gradually after 10 days of drying by lowering the W.B. The D.B. was increased to 110° F. on the 23rd day. In the more severe schedule, a D.B. temperature of 110° F. with a 5° F. W.B.

depression was used. The humidity was reduced after only 7 days of drying by lowering the W.B. The D.B. was increased to 120° F. on the 15th day.

Three units from each run were pulled from the low-temperature drier at a moisture content of 30 to 35 percent; the remaining 5 units per run were dried to 18.0 percent and 21.5 percent. One unit at 30 to 35 percent and one unit of 18 percent moisture content were trucked to the California Forest Products Laboratory, Richmond, for further drying studies. The remaining 14 units of the predried lumber were kiln dried in the company's commercial kiln.

KILN DRYING OF PREDRIED LUMBER

The kiln drying experiments were confined to drying lumber from the yard, shed, or low-temperature drying to the desired low final moisture content. Two kiln charges of lumber that had previously been predried to two levels of moisture in low-temperature driers were dried to a final moisture content of 8 or 9 percent. Two kiln charges of air-dried lumber were dried to a final moisture content of 7 or 8 percent and one kiln charge of shed-dried lumber was "finished off" to a uniform final moisture content of 7 percent.

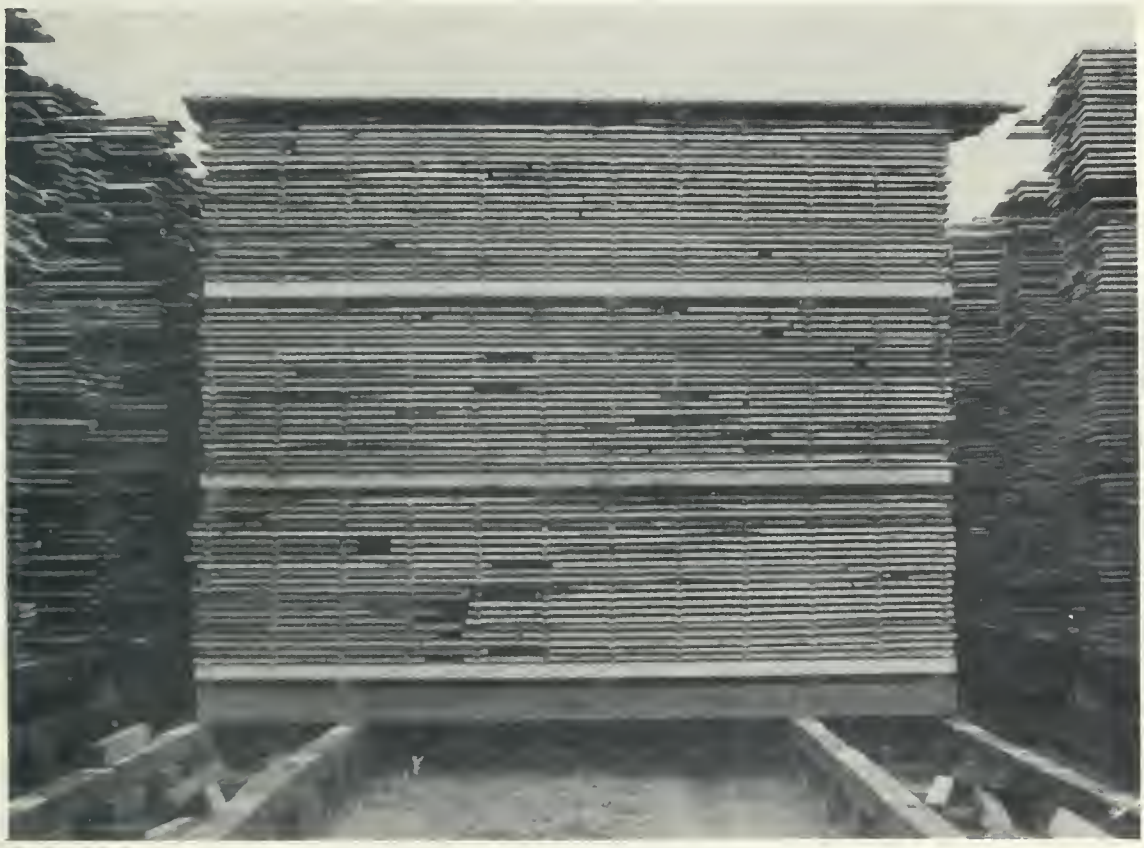

Figure 2.--Unit packages of 4/4 California black oak piled on air yard. Three-inch white fir used for "bottom boards."

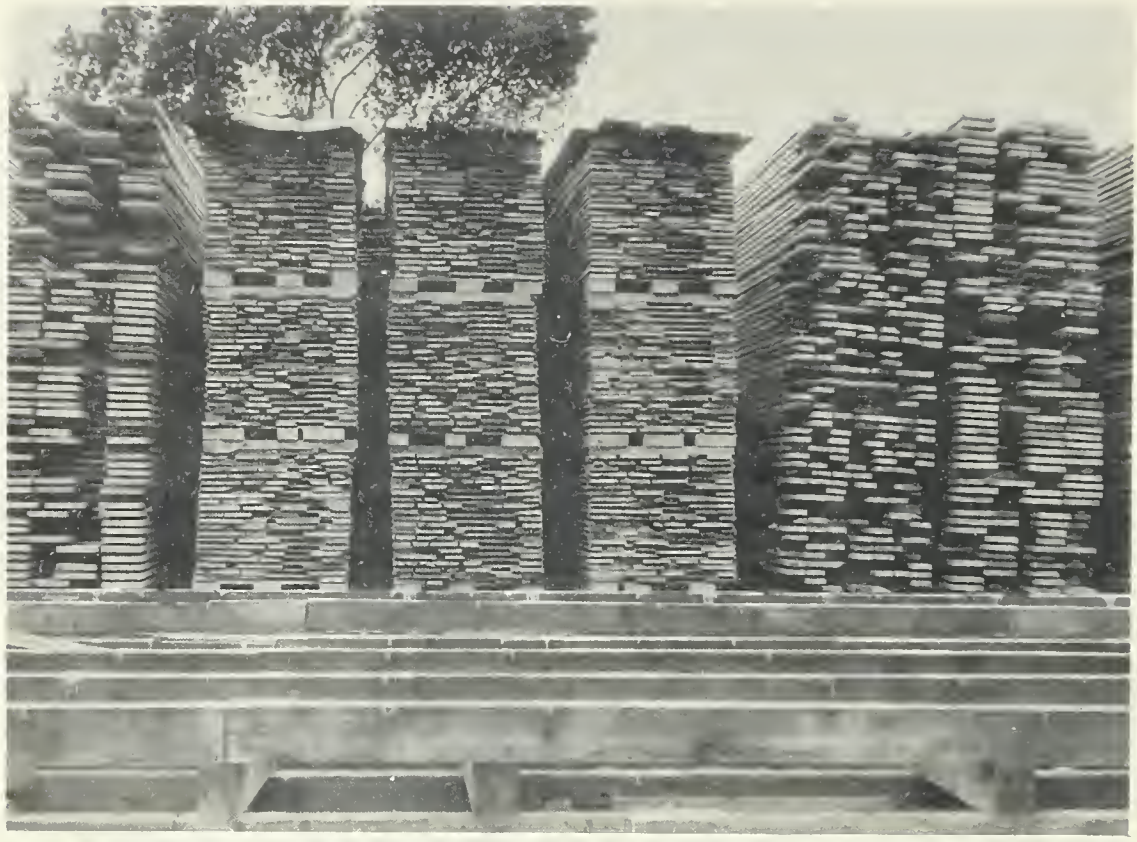

Figure 3.--Fifteen-inch spacing of unit packages of California black oak on air yard. Cover boards and paper used for pile roofs.

Lumber in all kiln charges was conditioned to relieve drying stresses. The kiln temperatures used during the conditioning treatment were 180° F. D.B. and 170° F. W.B. (equilibrium moisture content of 11.1 percent), and were maintained for 18 hours to relieve the drying stresses.

SHRINKAGE OF WIDE, FLAT-SAWED BOARDS

One objective of this study was to learn something about the shrinkage of California black oak lumber during drying. Selected, wide, flat-sawed boards were measured in width with a hookrule, usually in two places along the length of each test board. A line was marked across each board at the place the green measurement was made so that subsequent measurements would be in the identical place.

Two hundred and thirty-two measurements were made on green lumber and again after low-temperature drying. Two hundred and thirteen measurements were made on green lumber before shed drying, and one hundred and twenty-eight measurements were made on green lumber before air drying. All samples were remeasured after kiln drying.

RESULTS

RATE OF DRYING

The rate of drying of lumber in piles spaced 30 inches on the yard was only slightly faster than for lumber in piles spaced only 15 inches (fig. 5). All the air-dried lumber showed very little checking or other types of defects. Lumber in unit packages that were close piled in the shed dried surprisingly fast (fig. 5).

Accurate comparison of degrade in yard-dried and shed-dried lumber was difficult because of the great difference in the green grades of the lumber, the shed-dried lumber being only the lower grades. It showed no serious defects, however, and may have been somewhat better than the yard-dried lumber. This would be expected since the shed-dried lumber had complete protection from the weather.

Low-temperature drying by the more mild schedule (100° F. D.B. and 96° F. W.B.) reduced the moisture content of green 4/4 California black oak from slightly over 100 percent to 20 percent in 4 weeks (28½ days). In the more severe schedule (110° F. D.B. and 105° F. W.B.), the moisture content of the green lumber was reduced from 97 percent to 20 percent in less than 3 weeks (18 days)(figs. 6 and 7).

Drying defects that developed in the faster run were prohibitive, and a schedule similar to the first, or perhaps a more mild schedule, would be necessary to insure consistently good results.

The kiln drying of previously air-dried and low-temperature dried lumber required 9 or 10 days in this experimental drying, including conditioning, (figs. 8, 9, 10, and 11).

A moisture pickup of 2 percent during conditioning resulted in uniformly good stress relief. Samples with a cross-section average of 8 percent or more picked up very little; samples that had dried to a moisture content of 6 percent or less increased approximately 2 percent. There appeared to be little danger of overconditioning; even samples that increased in moisture content by 2.5 to 2.8 percent showed only slight reverse stress (fig. 4).

DEGRADE AFTER KILN DRYING

The effectiveness of the different combinations of predrying and kiln drying was measured by grading the lumber when green after predrying, and again after kiln drying. The degrade of lumber predried to 20 percent in the two low temperature runs and then kiln dried, amounted to 6.0 percent of green lumber tally. The degrade for lumber predried to a moisture content of 30 percent in the low-temperature runs and then kiln dried, was 8.4 percent. The combined degrade for all lumber, air dried, shed dried, and low-temperature dried, was only 3.6 percent. These figures indicate that much of the degrade developed either during low-temperature drying or in the kiln drying of lumber that had been only partially dried in the low-temperature driers.

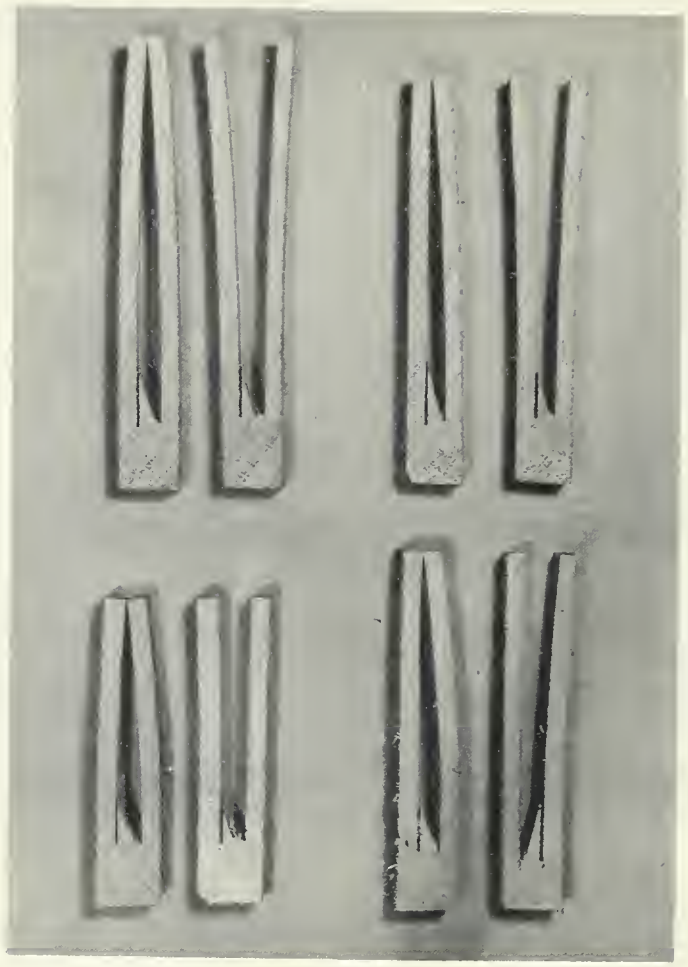

Figure 4.--Stress sections before and after conditioning, for samples that increased in moisture content of 2.5 to 2.8 percent during conditioning. Left section of each pair is "before conditioning."

But this method of measuring effectiveness did not present an accurate picture of drying defects for two reasons: (1) standard hardwood lumber grading rules permit a loosely defined amount of surface checking; (2) most of the degrade was found to be in lumber from certain logs. Mr. A. C. Wallin, of the U.S. Forest Products Laboratory, who did the grading, analyzed the data and found that 5 logs from only 2 trees accounted for 53 percent of the degrade. The remaining 47 percent was spread over 42 other logs. The result was a biased sample.

His analysis also showed the character and distribution of drying defects as follows:

	Percent
Collapse	67.9
Checks	13.9
Warp	
Cup	5.1
Crook	4.2
Twist	2.1
Splits	3.9
Shrinkage	1.0
Other	1.9
Total	100.0

To further measure the drying degrade in this predried, kiln-dried lumber, a sample of about 7,000 board feet was surfaced to 13/16 inches in thickness and then regraded, first on the basis of only the natural defects in each piece and then on the basis of these same natural defects plus drying defects such as checks, splits, warp, shrinkage, and collapse. This re-evaluation showed large differences in the percent of the total board footage that dropped one or more grades (table 1). In each case, lumber predried to 20 percent moisture had the smaller amount of degrade.

A sample from the 30 units of air-dried on the yard and shed-dried lumber was also re-examined after resawing to see if resawing revealed internal checks and honeycomb that could not be detected during grading as rough lumber. Results were quite different from those for the low-temperature dried lumber. The resawed surfaces showed no checks or honeycomb that would alter the grade. Neither yard drying nor shed drying resulted in enough surface or internal defects to affect the grade or full utilization of the stock for remanufacture.

SHRINKAGE OF WIDE, FLAT-SAWED BOARDS

Width measurements on 573 boards when green and again after drying to approximately 7 percent showed a consistent shrinkage in width of about 6 percent (table 2). These selected test boards averaged 10.17 inches wide, and shrinkage figures approach shrinkage in the true tangential direction. Edges of many boards, however, were partially quartersawed, therefore the measurement is not equal to tangential shrinkage determined by standard laboratory methods.

The figures for the low-temperature dried and kiln-dried lumber indicate that there is appreciable shrinkage when only a small surface zone has dried below 30 percent and the cross-section average of the piece is still very high.

During the early stages of drying, the inner portion of California black oak lumber is apparently subject to considerable compression. Overall shrinkage, therefore, becomes evident almost as soon as drying begins.

Table 1.--Degrade in predried, kiln-dried 4/4 California black oak as determined by regrading surfaced lumber

Item	Number of boards degraded 1 or more grades	Board footage degraded 1 or more grades
	Percent	Percent
LOW-TEMPERATURE DRIER RUN NO. 1		
Dried to 30-35 percent then kiln dried	19.3	25.4
Dried to 20 percent then kiln dried	5.4	1/ 6.0
Combined (weighted)	10.7	13.5
LOW-TEMPERATURE DRIER RUN NO. 2		
Dried to 30-35 percent then kiln dried	34.5	1/ 34.4
Dried to 20 percent then kiln dried	13.1	16.0
Combined (weighted)	21.6	23.5
LOW-TEMPERATURE DRIER RUNS NOS. 1 AND 2		
Predried to 30-35 percent then kiln dried	28.4	30.7
Predried to 20 percent then kiln dried	9.9	11.7
Combined (weighted)	17.1	19.3

1/ Boards dried in low-temperature drier Run No. 1 to 20% moisture content that had degraded during kiln drying (6%) lost only one grade while most boards dried in low-temperature drier Run No. 2 to 30-35% moisture content that had degraded during kiln drying (34.4%) lost more than one grade.

Table 2.--Average shrinkage of wide flat-sawed California black oak lumber during drying

Drying Procedure	Green, 100+ percent		Low-temperature dried, to 20-30 percent		Kiln dried to 6-7 percent	
	Width	Shrinkage	Width	Shrinkage	Width	Shrinkage
	Inches	Percent	Inches	Percent	Inches	Percent
Low-temperature dried and kiln dried	10.02	0	9.49	5.29	9.37	6.55
Air dried and kiln dried	10.51	0	--	--	9.93	5.25
Shed dried and kiln dried	9.98	0	--	--	9.34	6.36

Figures for shrinkage of boards between green and low-temperature dried (to moisture content of 20 to 35 percent) show that considerable shrinkage had already occurred.

The published figure for tangential shrinkage of California black oak[2/] (green to oven-dry, based on the green dimension) is 6.6 percent for 10 trees from Oregon and California. The figures in Table 2 seem to agree very closely with the earlier tests.

CONCLUSIONS AND RECOMMENDATIONS

An average moisture content of 20 percent was reached after about 9 weeks of air-drying during the favorable drying conditions that prevailed in Chico from April 15 to June 15, 1957. However, a longer air-drying time would be desirable to dry the lumber to an average moisture content well below 20 percent. Air-drying to a lower moisture content is added insurance of successful final kiln drying especially of the slow-to-dry boards and boards that may otherwise have wet areas beneath stickers.

2/ U. S. Department of Agriculture, Strength and related properties of woods grown in the United States, Table 1, U. S. Department of Agriculture Tech. Bul. 479. 1935.

If a cross-section average of 20 percent moisture content is necessary in each piece of lumber coming from the yard, drying times may be about as follows for lumber in properly roofed piles:

Date piled on yard	Months of air-drying to reach 20 percent in Chico
January 1	5
February 1	4-1/2
March 1	3-1/2
April 1	3
May 1	3
June 1	3
July 1	3
August 1	5
September 1	7
October 1	7
November 1	7
December 1	6

LOW-TEMPERATURE DRYING

California black oak can be dried in a low-temperature drier, but drying defects may result if certain limits are exceeded. A starting dry bulb temperature of 100° F. appears to be the highest that can be used. Higher temperatures may be safe toward the end of the low-temperature drying (from 30 percent to below 20 percent), and the drier should be designed to provide sufficient heating capacity to produce a dry-bulb temperature of at least 130° F.

At the start of a low-temperature drying operation, the maximum safe wet-bulb depression appears to be no greater than 5° F. if surface checking is to be controlled. This calls for accurate engineering of the heating system and a "tight" building. It also indicates that unless the temperature drop across the load is less than 5° F., drying will be retarded. The 5° F. wet-bulb depression also calls for reversible air circulation.

Figure 12 and Table 3 show conditions of D.B. and W.B. judged suitable for use in a low-temperature drier to dry 4/4 California black oak from green to 20 percent in about 40 days.

The amount of air circulation that is engineered into any low-temperature drier will be governed by cost of the installation and operation, and the air speed necessary to maintain acceptable uniformity of temperature across the load. Air velocities will also be governed by the length of air travel. Air speed of 250 feet to 300 feet per minute through the loads should be completely adequate, and lower air speed (200 feet per minute) may be all that is required for cross-circulation predriers with a relatively short air travel. Besides being more costly, high air speeds (up to 800 feet per minute) across the drying surface will require closer control of the temperature and humidity when the lumber is green.

Table 3.--Suggested low-temperature drier schedule for California black oak, using constant wet bulb temperature

Moisture content	Time	Dry bulb	Wet bulb	Wet-bulb depression
Percent	Days 1/	Degree F.	Degree F.	Degree F.
100 - 60	1 - 10	90	85	5
60 - 50	10 - 19	92	85	7
50 - 40	19 - 24	95	85	10
40 - 30	24 - 32	100	85	15
30 - 20	32 -	110	85	25

1/ Drying time estimated from drying curve based on results of this study.

For these reasons a moderate air speed (250 feet per minute) and relatively short air travel (12 to 16 feet) seem desirable. An air travel of 16 feet or less necessitates a kiln with cross-circulation, as opposed to longitudinal air flow with cross-piled lumber as in a tunnel-type kiln. A longer air travel will require much higher rates of circulation and booster coils.

FINAL KILN DRYING

Either air-drying or low-temperature drying, followed by kiln drying is the presently accepted method of drying oak in the East and South where oak lumber is produced commercially. The problem in drying California black oak is one of applying this well established procedure to local conditions. Fast kiln drying of predried lumber is possible when the wettest pieces have reached a cross-section average moisture content of about 20 percent, and the moisture content of the wettest areas is 30 percent or less. In setting up any kiln-drying procedure, an important consideration is that of having the whole charge dried below the fiber saturation point, even in the wettest parts. These wettest areas are likely to be in the centers of pieces at the stickers, particularly in those boards that are slow to dry.

Kiln schedules Nos. 3 and 4 (figs. 10 and 11) appear to be suitable for California black oak lumber that has previously been dried to an average moisture content of 20 percent.

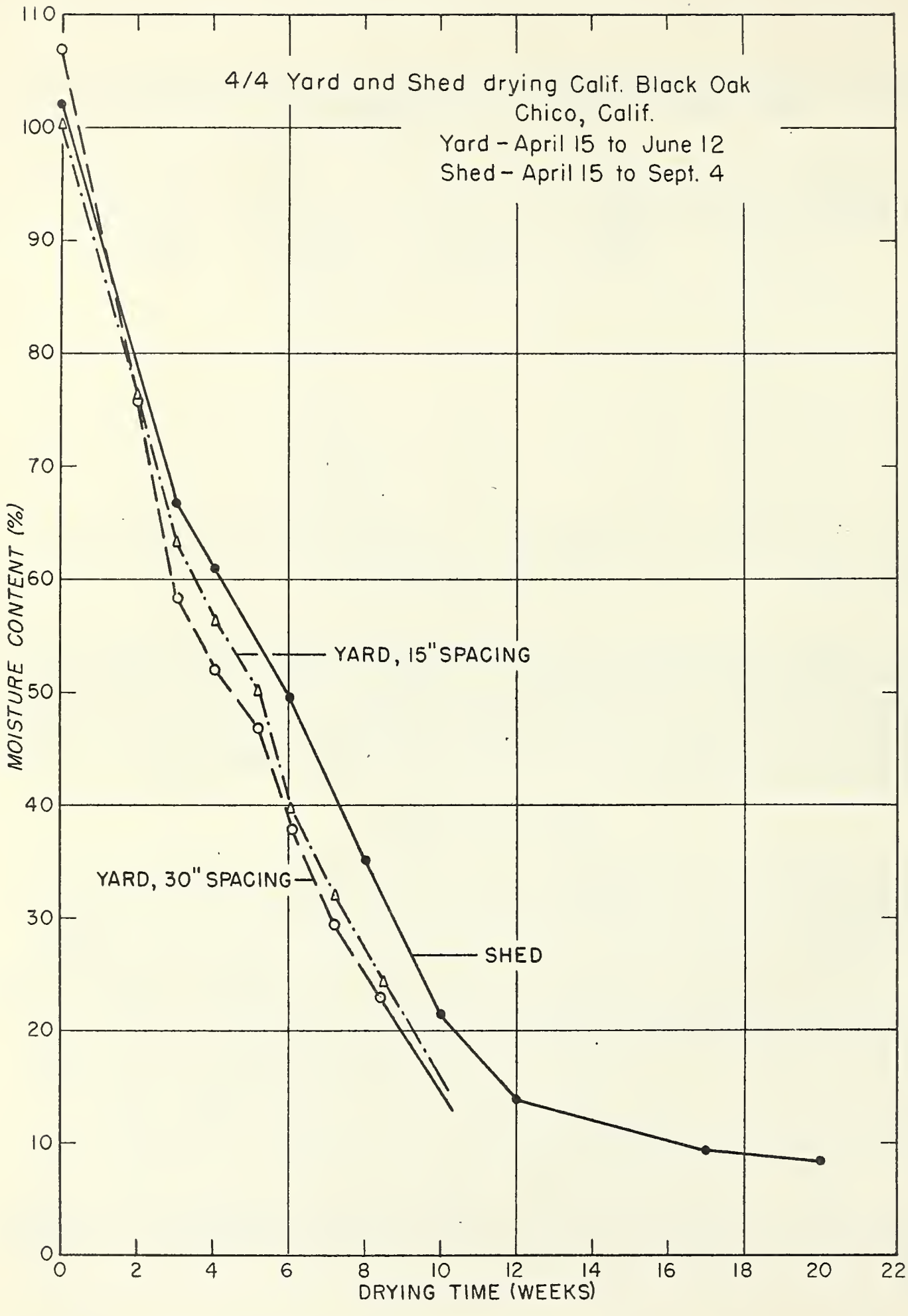

Figure 5.--Yard and shed drying 4/4 California black oak, Chico, California.

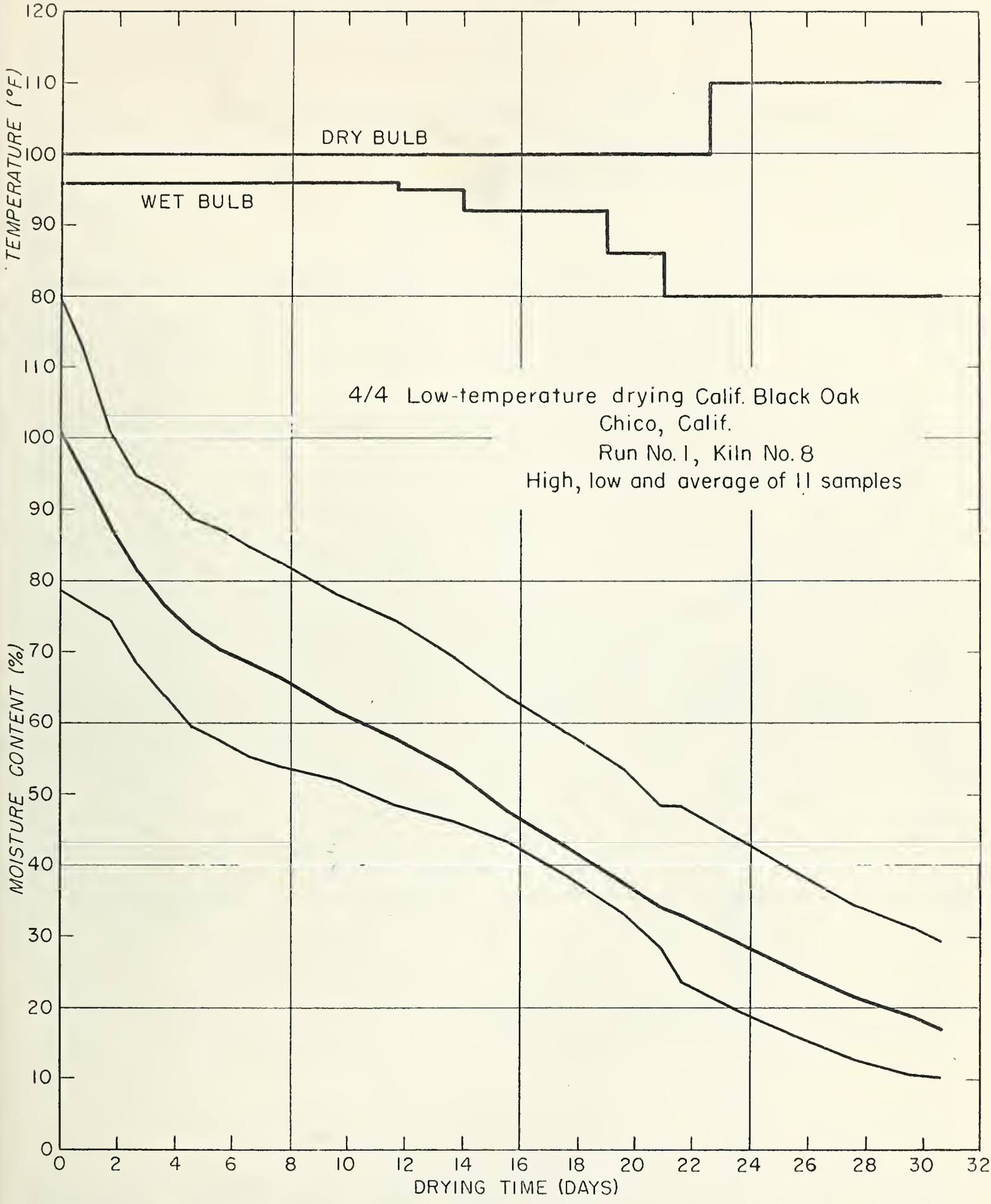

Figure 6.--Low-temperature drying 4/4 California black oak, Chico, California. Run No. 1, Kiln No. 8.

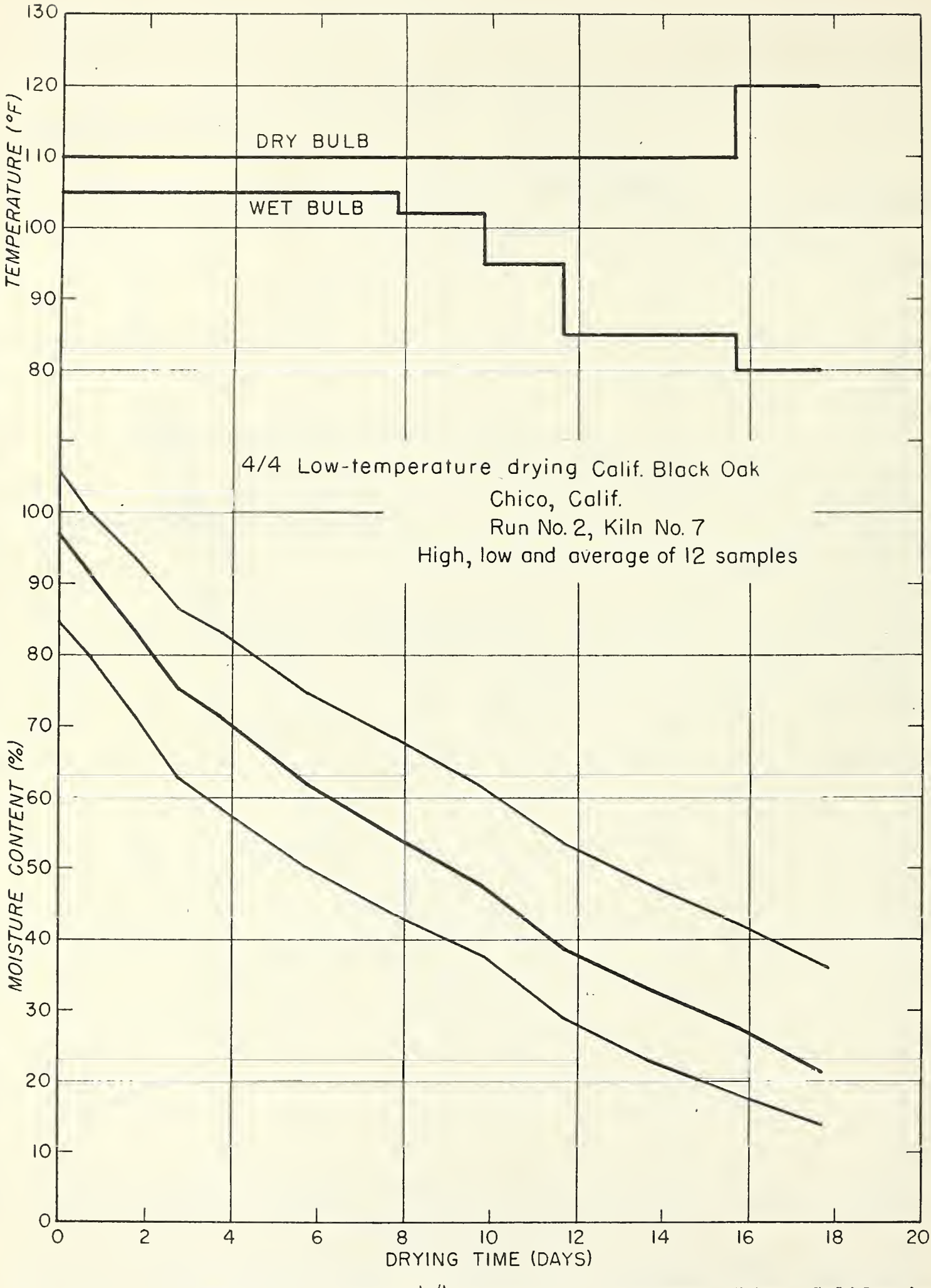

Figure 7.--Low-temperature drying 4/4 California black oak, Chico, California. Run No. 2, Kiln No. 7.

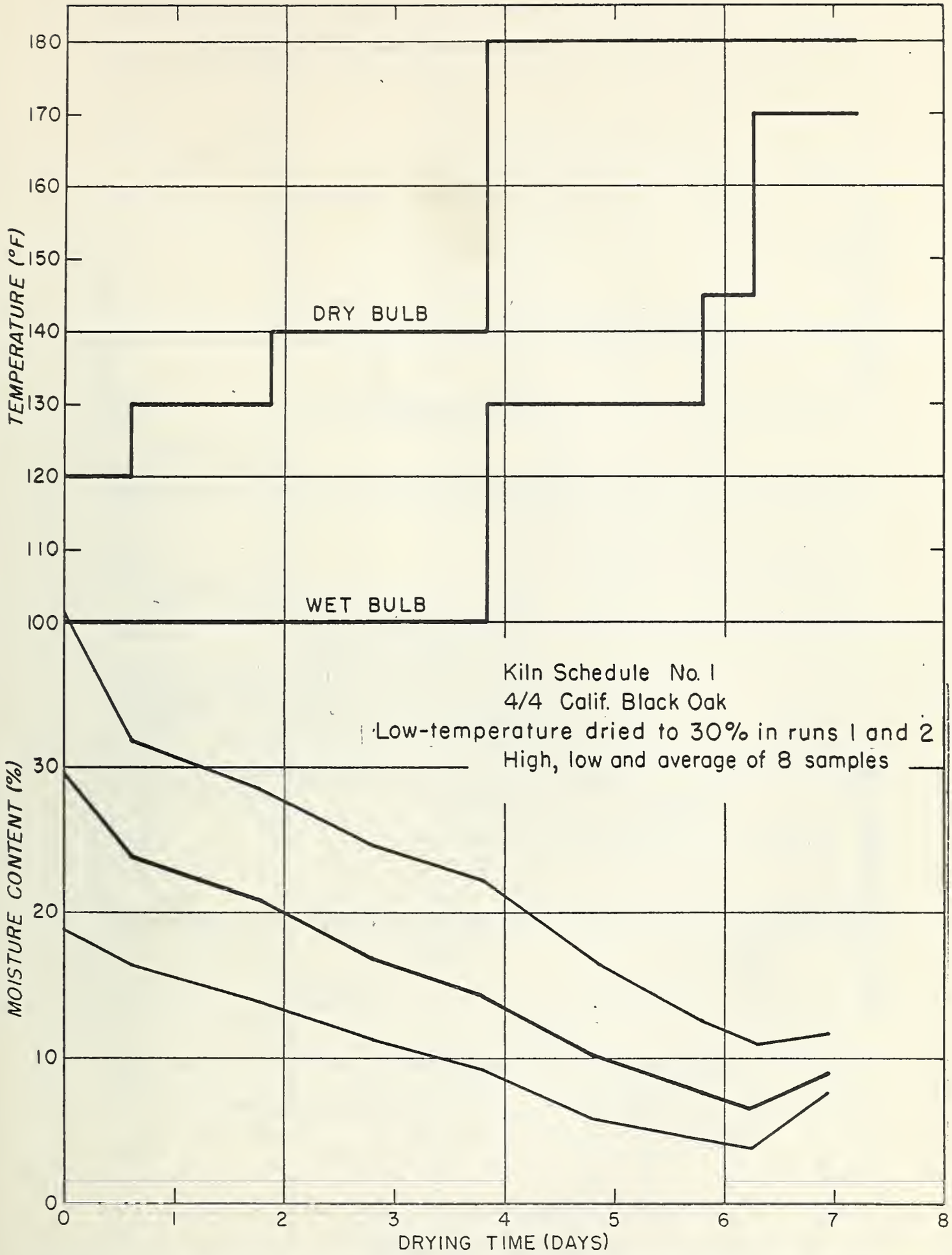

Figure 8.--4/4 California black oak low-temperature dried to 30%. In Runs 1 and 2, Kiln schedule No. 1.

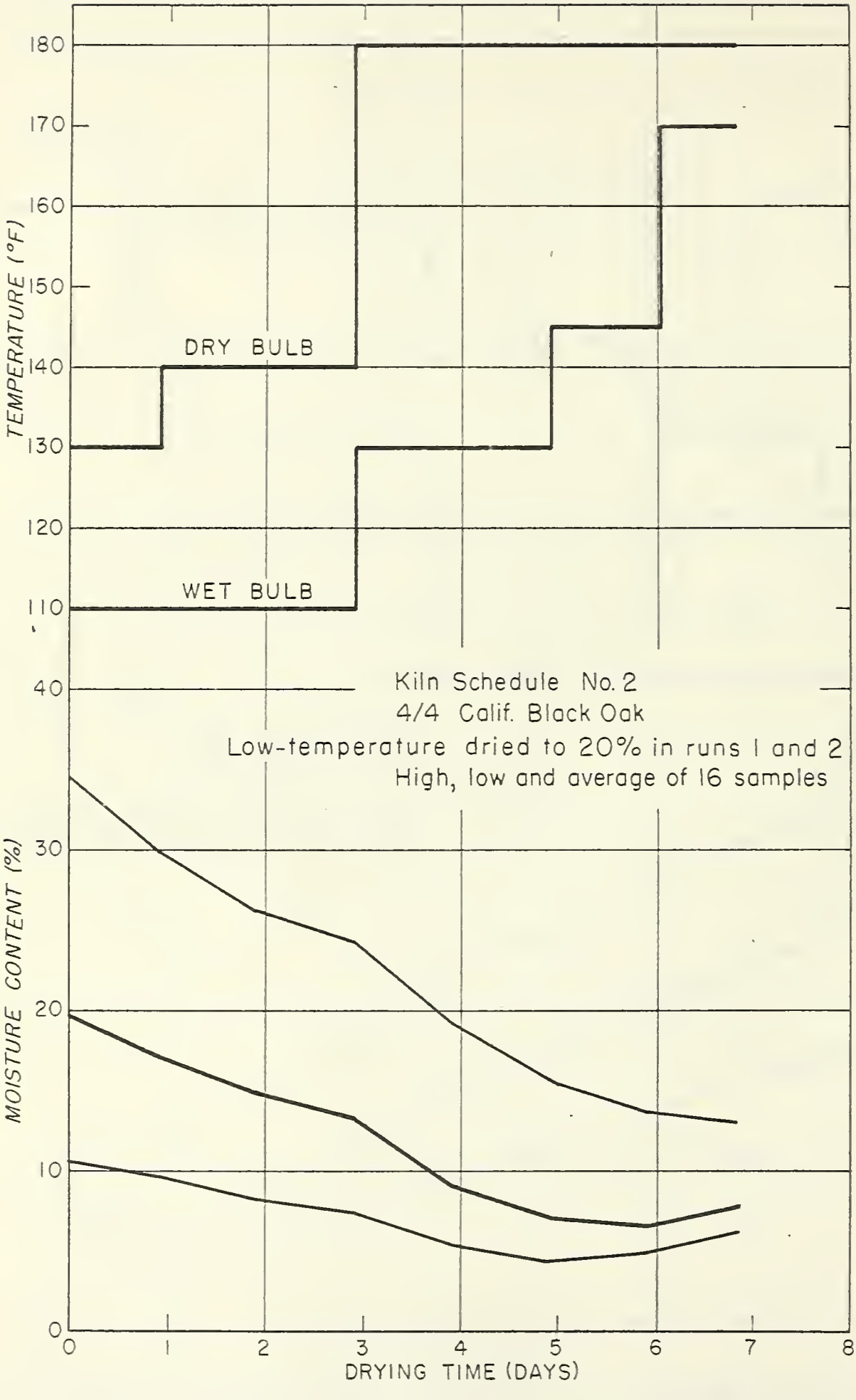

Figure 9.--4/4 California black oak low-temperature dried to 20%. In Runs 1 and 2, Kiln schedule No. 2.

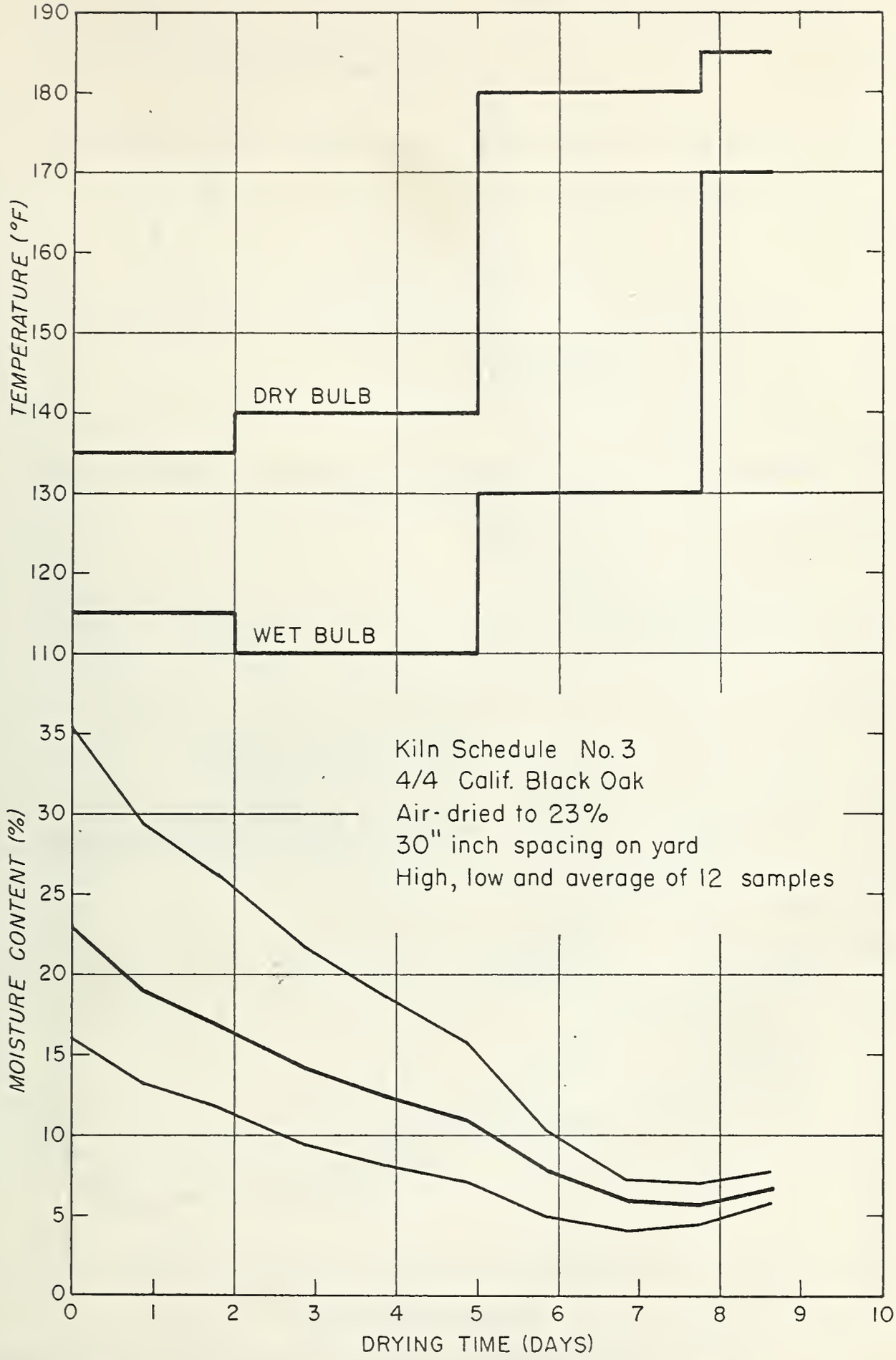

Figure 10.--4/4 California black oak air-dried to 23%. Kiln schedule No. 3.

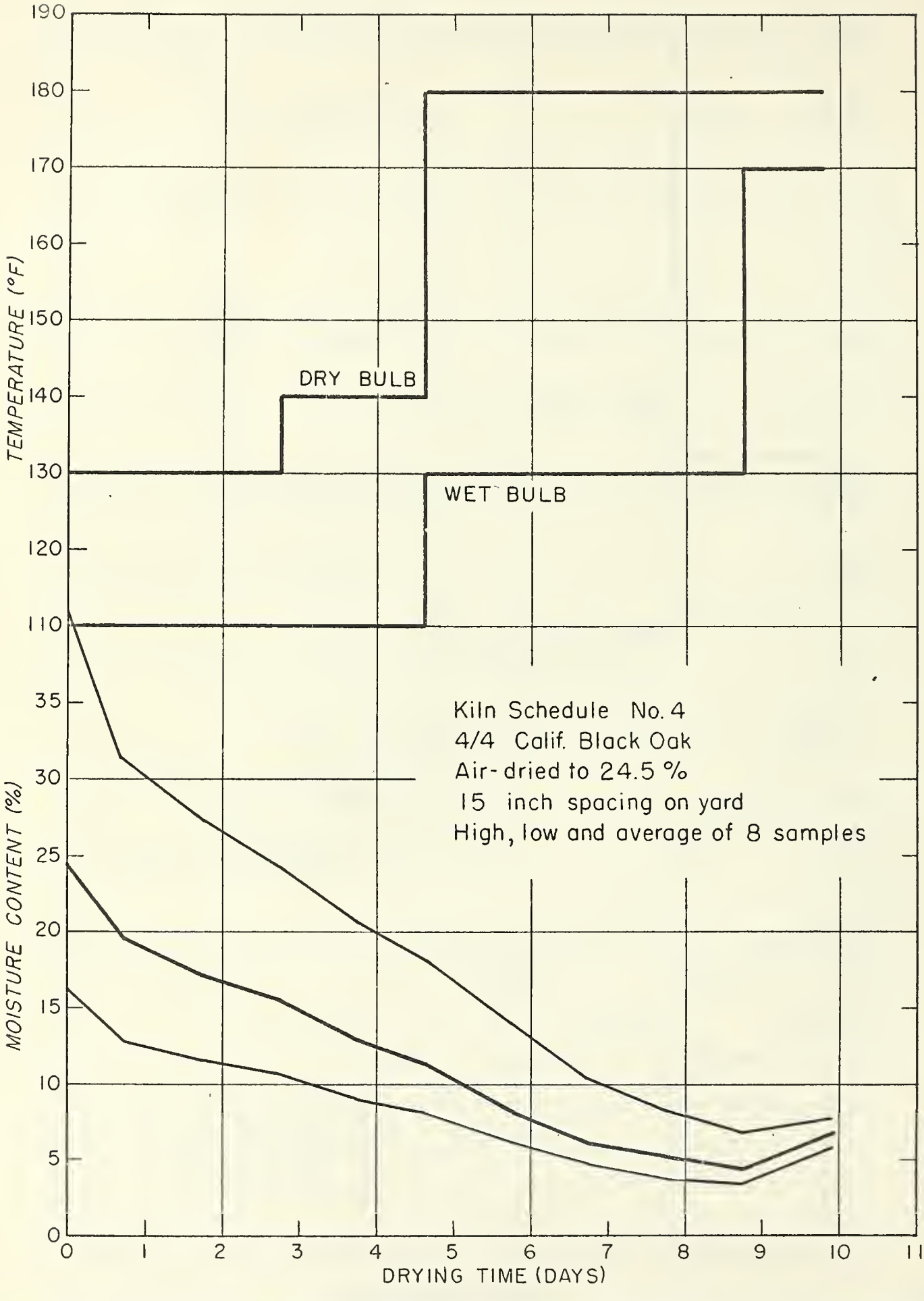

Figure 11.--4/4 California black oak air-dried to 24.5 %. Kiln schedule No. 4

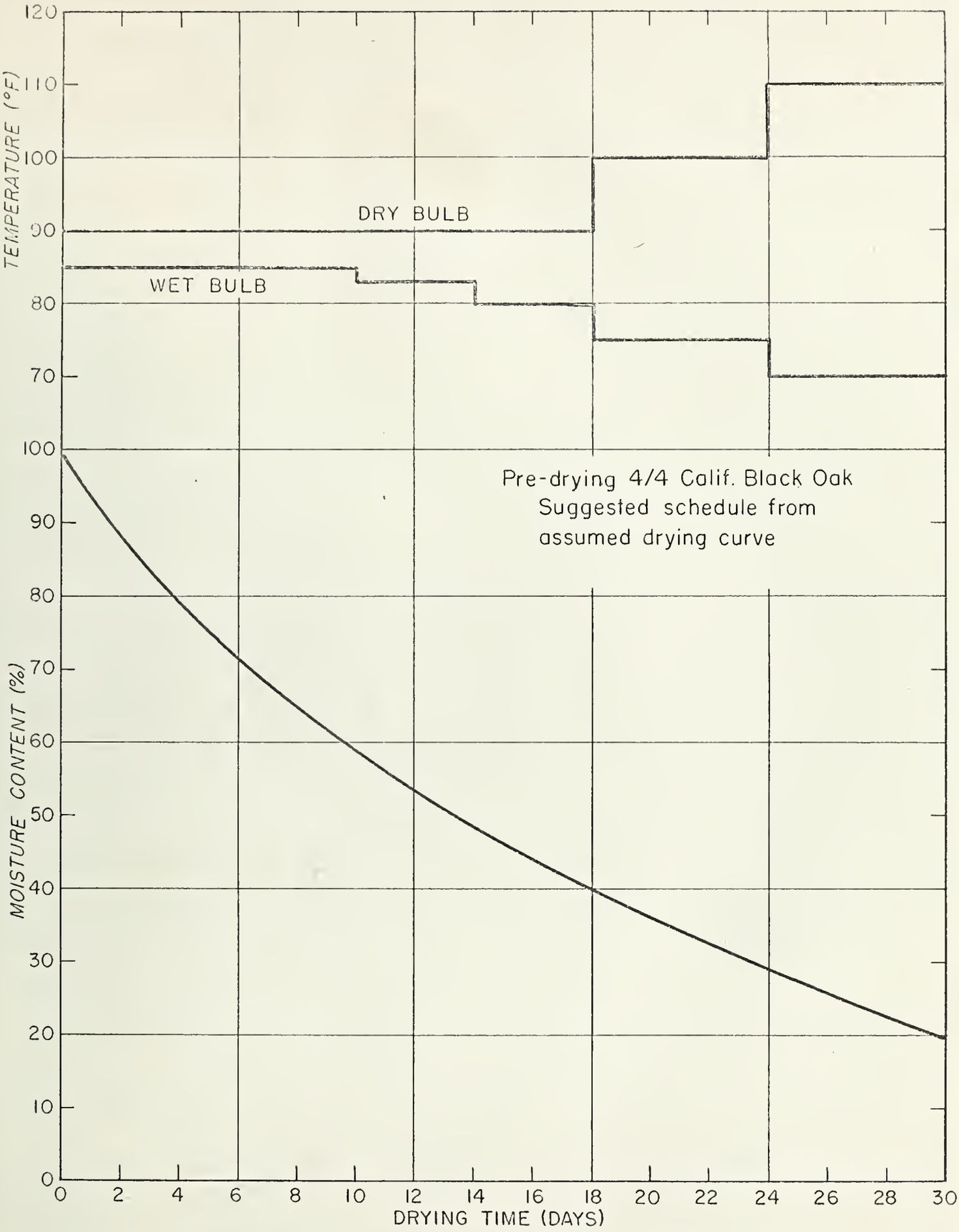

Figure 12.--Low-temperature drying California black oak. Dry bulb, wet bulb.

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